WASHINGTON STATE DEPARTMENT OF HEALTH
Wireless Communications Facilities
Position Paper

Washington State Department of Health

Purpose

The growing demand for wireless communication services has resulted in a convergence of industry, government, and public interests. Industry, under considerable pressure to establish reliable service, must identify and acquire sites suitable for communication facilities. Local governments must determine if selected sites conform with land-use zoning regulations. Some citizens voice concerns about neighborhood aesthetics and property values, and have questions about health effects of exposure to radiofrequency (RF) radiation emitted from wireless facilities. This document provides a brief summary of what is currently known about RF radiation exposure and health, exposure levels produced by wireless communication facilities, and federal RF standards. It concludes with Washington State Department of Health (DOH) findings and recommendations.

Background

Electric power, radiowaves, microwaves, infrared, visible and ultraviolet light, X-rays and gamma rays are all sources or examples of electromagnetic radiation. Ultraviolet light (UV-B & UV-C), X-rays and gamma rays, at the upper end of the electromagnetic spectrum, have sufficient energy to cause direct ionization of atoms[1]. Exposure to ionizing radiation has been linked to cancer and genetic mutations in biological tissue.

Microwaves, radiowaves, (including those used by wireless communications), and electric power use frequencies that lack the energy to ionize atoms and, thus, are included as part of the non-ionizing electromagnetic spectrum. Non-ionizing radiation interacts with atoms and molecules in the body through mechanisms other than ionization. Interactions include those that result in tissue heating (thermal effects), interactions that cannot induce tissue heating (nonthermal or athermal effects), and interactions where both thermal and athermal effects occur simultaneously. Although a majority of known effects of exposure to non-ionizing radiation are attributable to thermal exposures, athermal effects have been demonstrated in both strong and weak RF fields. Some evidence suggests that athermal effects may include changes in the immune system and neurological or behavioral effects. However, contradictory experimental results have been reported, and further research is needed to determine whether these athermal effects are harmful to human health.

The interest in effects of RF radiation has increased, in part, because growth in technologies utilizing RF energy has resulted in more of the population being potentially exposed. Familiar applications include AM and FM radio, television, microwave ovens, and citizens' band radio. Less familiar are newer technologies that have become common in the past decade such as satellite communications, paging services, and wireless communications services.

Wireless communication uses radiofrequencies in the 800 to 2200 Megahertz (MHz) range. Originally called cellular communication because of the way geographic areas are divided into service areas known as "cells," wireless systems rely on fixed facilities, or base stations,

[1] Ionization is a process by which electrons are stripped from atoms.

where antennas are built. As a person travels from one cell to another, the communication from the telephone is “handed off” from the cell being left to the cell being entered.

Depending on the type of service available, cellular telephones transmit either analog or digitized voice messages. In analog communication systems, messages are transmitted by varying either the amplitude (height) or the frequency of the radio wave. Digital communication systems transmit messages as a series of digits in rapid bursts or pulses [1]. Both analog and digital systems, commonly known as "cellular systems," operate between 824 and 894 MHz. The latest generation of wireless communications, called Personal Communications Services (PCS), is similar to cellular telephone service. In this system, digital technology delivers voice, data, and video images. PCS operates in a higher frequency band (1850 to 2200 MHz) than cellular systems and utilizes a very localized wireless network requiring smaller cells and more antennas than cellular service has in the past.

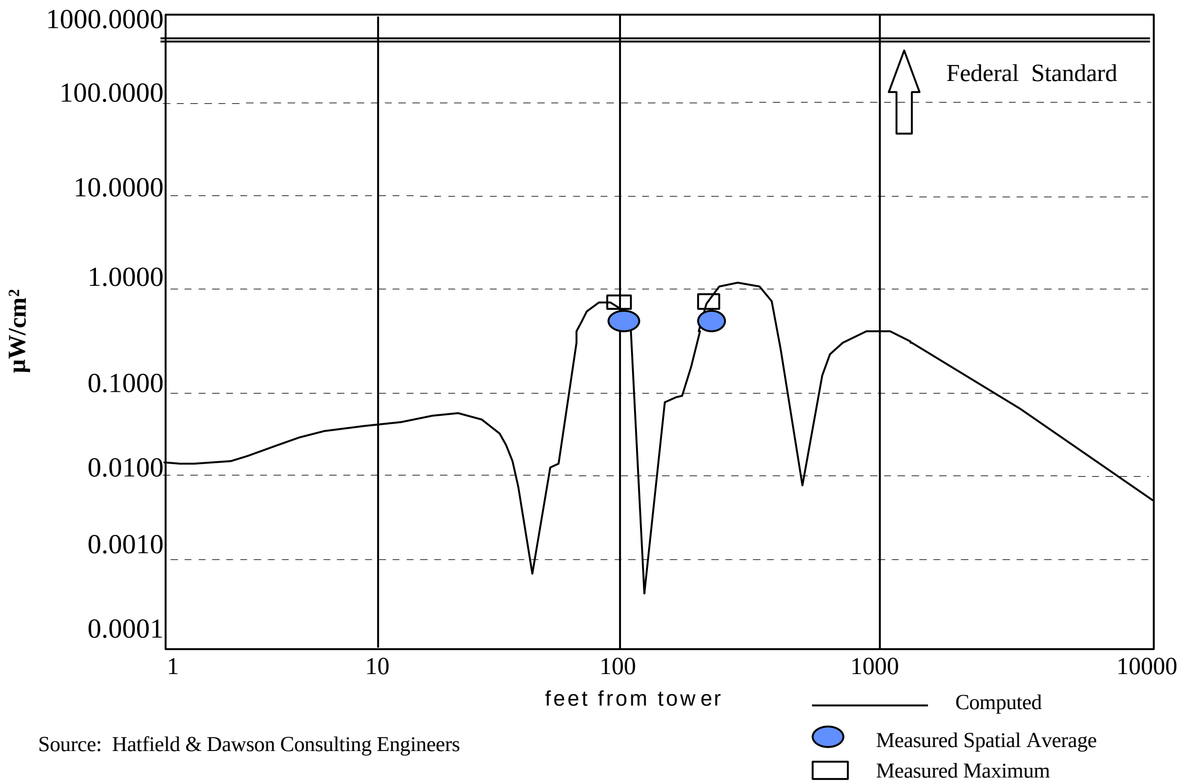
Locations chosen by wireless companies to site antennas depend on a variety of factors, such as the proximity of adjacent cell sites, engineering and topographical considerations, community response and the existence of a willing property owner. A typical site consists of a small structure to house electronic equipment, radio transmitters, and receivers. Some facilities are placed on existing structures such as rooftops or buildings. Other sites are created by placing antennas on towers or monopoles. Towers, buildings, and transmitters can be shared by multiple users.

Radiofrequency Exposure Levels from Wireless Antennas

RF exposure levels are described in terms of power density, which is the rate at which energy flows through a defined area. The measure of the rate at which energy is flowing is the watt (W), and the measure of the area is usually the square centimeter (cm^2). Power density may therefore be measured as watts per square centimeter (W/cm^2) or, for levels produced by wireless communication, as microwatts (i.e., one-millionth of a watt) per square centimeter ($\mu W/cm^2$).

The power density from a wireless antenna decreases rapidly with the square of the distance as one moves away from the antenna. However, because RF energy travels as waves, there are effects from reflections, interactions among waves from multiple antennas and spikes of intensity due to each antenna pattern. This produces a pattern of peaks and valleys in field intensity as one moves away from the source [1]. The intensity of RF energy depends on several factors, including design characteristics of the antenna, power transmitted to the antenna, height of the antenna, and distance from the antenna. Figure 1 shows computed and measured power density levels at various distances from an antenna. This figure illustrates how power density levels are lowest directly under the antenna and then increase variably up to about 800 feet from the tower, at which point they begin a steady decline. Spikes and peaks in intensity are evident due to reasons explained above.

FIGURE 1. COMPUTED & MEASURED POWER DENSITY -
1800 Watts ERP



Source: Hatfield & Dawson Consulting Engineers

RF exposures differ according to whether a facility is a stand-alone tower or placed on the rooftop of a building. The most common exposure situation occurs with antennas placed on towers. Maximum power density measured at the average height of an adult in the vicinity of typical cellular transmission towers ranging in height from 150 to 269 feet is less than 0.01 μW/cm² per channel. Thus, for a 96-channel system operating with an effective radiating power (ERP) of 100 W per channel, the aggregate maximum power density exposure to an individual would be less than 1.0 μW/cm² [2].

Another exposure condition results from antennas placed on rooftops. Measurements made at less than 5 feet from a rooftop-mounted panel antenna beam are about 200 μW/cm² for one channel and about 4,000 μW/cm² for 19 channels at 100 W ERP per channel. At 20 feet, the 19 channel reading drops to 200 μW/cm². While the 19 channel exposure at less than 5 feet exceeds exposure standards, this location is likely to be inaccessible due to physical barriers preventing access to the antenna [3]. Note how in the examples given, rooftop exposures are higher than typical ground level exposures from towers. This is because on rooftops, individuals can be at or near the same height as an antenna and in closer proximity.

Table 1 shows calculated power densities at various distances from a typical suburban cell site. The exposures are generally low due to the height of the antenna and the fact that RF energy is directed horizontally from the antenna.

Table 1. Calculated Power Density for a Typical Suburban Cell Site*			
Distance from Tower (ft)	Distance from Antenna (ft)	Channels Power Density ($\mu W/cm^2$)	% of Allowable Limit
0	94	0.067	0.011%
10	94.5	0.066	0.011%
50	110	0.46	0.078%
100	140	1.6	0.27%
120 (maximum)	150	1.8	0.30%
200	220	0.12	0.020%

*100 foot tower, 12 channels, 100 W ERP/Channel, operating at 880-894 Mhz. Exposures include 60% reflected energy from the ground.
Source: R. Maiorano, Systems Engineer, Airtouch Cellular, 2/27/97

The increased demand for wireless services places additional constraints on the service area for each antenna. As the number of customers in a given area increases, the power level for a given antenna must be reduced in order to allow for "re-use" of the same frequency in another geographic location. The result is more antennas with a lower ERP, although the number of channels per location will generally increase to handle the greater load. For example, an existing antenna may use 100 W ERP with 12 channels for a total ERP of 1200 W; a newly placed antenna may use 20 W ERP with 24 channels for a total ERP of 480 W.

Power levels used by cellular antennas are significantly lower than the power typically used for TV broadcasting. For example, the allowable ERP for TV channels 7-13 (174 to 216 MHz) is 316,000 W, and for channels 14 to 69 (470 to 806 MHz), the allowable power level is 5,000,000 W. TV broadcasting, as a result of the greater ERP, requires far fewer antenna stations to obtain the desired coverage.

An issue of interest is whether a combination of mixed frequency fields (e.g., FM, AM, and TV broadcasts combined with those used for wireless communication) results in an overall exposure level exceeding the allowable limit. Table 2 shows RF radiation exposure levels from typical FM antennas, VHF antennas, UHF antennas and cellular antennas. Levels of RF energy from the FM, VHF and UHF antennas were estimated from survey data collected by the US Environmental Protection Agency (EPA). The survey found average exposure levels from each type of antenna to be 0.005 $\mu W/cm^2$ [4]. In a hypothetical example using the upper bound EPA survey levels and cellular exposure levels described in the preceding section, RF levels from FM, VHF, UHF and wireless antennas result in only a small fraction (1.4%) of the allowable combined limit.

Table 2.	**Limits Resulting from a Combined Mixed Field Exposure***		
Type of Antenna	Power Density ($\mu W/cm^2$)	Allowable Limit ($\mu W/cm^2$)	% of Limit**
FM (88 to 108 MHz)	1	200	0.5
VHF (54 to 88 MHz)	1	200	0.5
UHF (470 to 806 MHz)	1	425	0.2
Cellular (824 to 894 MHz)	1	570	0.2
Total Exposure			**1.4% of limit**

*Hypothetical scenario using reported reasonably maximum values from multiple antennas
**See section on RF standards

Federal Radiofrequency Emission Standards

The Telecommunications Act of 1996 contains provisions concerning the placement of antenna structures and other facilities for use in providing personal wireless services. As required by this law, the Federal Communications Commission (FCC) adopted guidelines for environmental RF emissions. These guidelines apply to all transmitters licensed or authorized by the FCC, including antennas licensed to wireless service providers and the cellular telephones used by subscribers to the service. The guidelines are based upon recommendations of federal agencies with expertise in health and safety issues.

The FCC adopted Maximum Permissible Exposure (MPE) limits for electric and magnetic field strength and power flux density for transmitters operating at frequencies used by wireless communication. These limits are generally based on recommendations made by the National Council on Radiation Protection and Measurements (NCRP) in 1986. With the exception of the limits on exposure to power density above 1500 MHz and the limits for exposure to lower frequency magnetic fields, these MPE limits are also generally based on the guidelines contained in the 1992 RF safety standard developed by the Institute for Electrical and Electronics Engineers, Inc. and adopted by the American National Standards Institute.

The FCC recommended guidelines for occupational exposure are a factor of 10 less than the lowest statistically significant levels where observed thermal effects occurred. Public limits are an additional factor of five less than the occupational limits to account for the possibility of continuous exposures and the increased sensitivity of children and the elderly. The public limit is therefore a factor of 50 less than the lowest observed level where thermal effects are observed.

The limits for exposure are defined in terms of incident field strength or power density. Table 3 shows RF exposure limits expressed in terms of power density in the two frequency ranges used by wireless communication. The occupational exposure limits displayed in Table 3 are based on a six minute interval in order to limit the total absorbed energy to within a specific quantity. The public exposure is limited to the same total energy absorption as the occupational limit but allows a longer averaging time for the exposure.

The result for public exposure is a lower specific absorption rate[2]. Limits differ between cellular and PCS frequencies because the higher frequency (PCS) is absorbed in the body less efficiently. The result is a higher allowed power density that would give a similar total absorbed energy.

Table 3. FCC RF Exposure Limits for Wireless Communications

Frequency	Occupational Exposure Limits (Averaging Time = 6 min.)	General Public Exposure Limits (Averaging Time = 30 min.)
824-894 MHz (Cellular)	2746 μW/cm^2 - 2980 μW/cm^2	549 μW/cm^2 - 596 μW/cm^2
1850-2200 MHz (PCS)	5000 μW/cm^2	1000 μW/cm^2

FCC adoption of these standards preempts state and local governments from basing regulation of the placement, construction or modification of personal wireless facilities directly or indirectly on the environmental effects of RF emissions. Specifically, Section 704 of the 1996 Telecommunications Act states:

> "No State or local government or instrumentality thereof may regulate the placement, construction, and modification of personal wireless service facilities on the basis of the environmental effects of radiofrequency emissions to the extent that such facilities comply with the Commission's regulations concerning such emissions [5]."

The FCC notes that research and analysis relating to RF safety and health is ongoing, and changes in recommended exposure limits are expected to occur in the future as knowledge increases in this field. The FCC intends to continue its work with industry and the various agencies and organizations with responsibilities in this area in order to ensure that guidelines for protection of human health continue to be appropriate and scientifically valid.

Scientific Research

Standards are set to protect exposed persons from unacceptable risks of harm. The basis for the FCC standards draws from over 10,000 published studies of the possible effects of RF radiation in the areas of cancer initiation and promotion, of reproductive failures (such as spontaneous abortions and congenital malformations), and of effects on central nervous system function. The most clearly demonstrated adverse health effects of RF radiation are primarily caused by excessive body heating. Less is known about the health risks from effects that do not cause tissue heating.

Biological Studies

Biological studies of RF radiation exposure are of two general types, *in vitro* studies at the cellular level, and *in vivo* studies on living animals. Thus far, the outcome of greatest interest in biological studies has been carcinogenic effects resulting from exposure to RF radiation.

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[2] Specific absorption rate is the rate that radiofrequency energy is absorbed into a given mass, measured in units of W/kg.

In 1986, the NCRP concluded that there is no well-documented evidence that exposure to RF radiation increases the risk of cancer induction in humans or experimental animals [6]. Several reviews on the existing data have been performed since the NCRP review [7-10], further exploring the possibility of RF radiation as an initiator of cancer. Reviews of the *in vitro* studies [11, 12] concluded that many of the positive findings of RF-induced DNA strand breaks, sister chromatid exchanges, or chromosome aberrations occurred under thermal conditions or were due to other experimental factors [13, 14]. *In vivo* (animal) studies have provided conflicting results [8], but no elevation in the rate of sister chromatid exchanges or chromosome aberrations have been observed following athermal exposures.

Recent *in vivo* studies have provided some indication that DNA damage may occur at athermal specific absorption rates [15-17]. In a recent study, single and double strand DNA breaks observed in previous studies were blocked with the use of free radical scavengers[3] [18]. One interesting finding in this series of studies is that the observed single and double strand breaks continued to be observed for up to four hours after exposure, indicating a possible continuing effect from the source of the damage and/or inhibition of the normal enzymatic repair mechanism; however, replication of these studies is needed before definitive conclusions can be drawn.

Exposure to RFR has been reported to cause a variety of effects on biochemical, neurologic, immunologic, hematologic, genetic, developmental, neuroendocrine and cellular endpoints in mammals [6]. Although sufficient evidence exists to clearly demonstrate both the detrimental and beneficial effects of RF radiation under thermal conditions, it has not been ruled out that some may be caused by athermal mechanisms, as well.

The biological studies performed to date have some limitations. The studies are generally based on acute, high-level exposures, whereas actual exposure situations usually occur over longer periods of time at lower exposure levels. The studies are also based on animal research and have not been conducted using the unique operating characteristics of wireless communication such as digital systems which utilize a pulsed frequency modulated field. The biological studies conducted at power levels that are thought to induce athermal effects have additional limitations beyond those that apply to RF exposures which induce thermal effects. Research conducted on athermal effects has been highly dependent on exposure conditions and environmental variables such as temperature and the types of cells or tissues and endpoints studied. Results have been transient, small in magnitude, and difficult to relate to harmful health effects [7].

Epidemiologic Studies

The search for reliable and significant relationships between exposure and disease in a population is the task of epidemiologists. Epidemiologic data from a collection of studies, when combined with controlled laboratory and animal study data, can suggest a causal effect between an exposure and disease. To date, epidemiologic investigations of human exposure to RF radiation specifically from wireless communication facilities have not been conducted. Thus, given the absence of data, it is not possible to ascertain the safety of wireless facilities based on epidemiologic evidence.

[3]A free radical is an atom containing a single unpaired electron, rendering it highly reactive.

There have been, however, studies looking at health outcomes (usually cancer) in persons living or working near other types of facilities that produce RF energy. Whether or not these results can be used to evaluate health risks in people who live or work near wireless communication facilities is unclear. In addition, results of these studies have been equivocal and interpretation of findings is difficult. For example, early cohort studies of US foreign service workers exposed to very low levels ($\leq 18\ \mu W/cm^2$) of microwave radiation (600 to 9500 MHz) and military personnel exposed to radar (600 to 9500 MHz) did not find significantly elevated rates of cancer [19, 20]. However, subsequent cohort studies found statistically significant risks of lymphatic and hematopoietic neoplasms in amateur radio operators (Standardized Mortality Ratio=1.76 for acute myeloid leukemia) [21-23] and in Polish military officers exposed to radar [24].

Results of ecological studies of persons living near radio and television broadcast antennas, which operate at frequencies different than those used by wireless communication facilities, have been reported. In Hawaii, statistically significantly increased standardized incidence ratios (SIR) for all cancers combined were found in residents living in close proximity to radio/TV towers (SIR=1.88, $p<0.01$) [25]. More recently, increased risks for leukemia have been shown in persons who lived around broadcast facilities in Australia and Great Britain [26-28]. In Great Britain, results showed a statistically significant increased risk of adult leukemia (Odds Ratio=1.83, 95% Confidence Interval (1.22-2.74)) near the Sutton Coldfield transmitter, but not in areas located near other transmitters. Interpretation of results of ecological studies such as these is problematic because, by design, they do not directly link specific exposures to specific health outcomes in specific individuals, nor do they usually address potentially confounding factors except for demographic characteristics obtained from census records.

While there is little epidemiologic evidence to suggest risks of non-cancer endpoints such as reproductive or developmental effects in humans exposed to RF radiation, research has been limited. The reported results are equivocal and have not been replicated. Investigation of ocular effects, especially cataracts, have been conducted on military personnel exposed to RF radiation at military installations. These studies have generally demonstrated no excess risk of non-cancer health effects due to RF radiation [29].

Several limitations of the epidemiologic research must be considered. In general, epidemiologic studies have limited capacity to detect low-level risks. In some studies, case identification is problematic; in others, response rates are low. Cohort studies of RF exposure provide some evidence of increased risk of various cancers, but problems with small sample sizes, short periods of follow-up, and lack of exposure data limit their usefulness in determining risk.

This absence of exposure data represents a major limitation in all of the epidemiologic studies. While various approaches have been used to estimate exposure, none have determined actual exposure and dose for individuals or groups. Without well-developed exposure data, it is difficult to analyze possible dose-response relationships and to interpret the significance of findings. Therefore, research at frequencies used by wireless communication facilities at appropriate power levels must be conducted before epidemiologic evidence can be used to assist in drawing conclusions about wireless facilities and health.

Findings

Based upon the above discussion, the DOH concludes the following.

- Actual RF exposures from wireless communication facilities are, in most cases, only a fraction of the FCC-adopted guidelines. The most likely exception occurs at distances less than 5 feet from wireless base stations located on building rooftops, a position that is usually inaccessible.

- There is currently no conclusive evidence to suggest that exposure to RF radiation at levels produced by wireless communication facilities poses a risk to human health. However, certain factors must be considered:

Although there has been extensive research on the biologic effects of RF radiation, very little research has focused on exposure to RF used by wireless communications. If there are effects due to specific characteristics of wireless communication such as frequency modulation of RF signals, the existing research may not be relevant.

  - No research has been completed on the effects of long-term animal or human exposure to RF radiation from wireless communication.

  - Most research has focused on identifying and quantifying thermal effects of RF exposures; little is known about possible athermal effects, although most of the evidence collected to date has demonstrated no increased risks.

- Given the current state of knowledge, the DOH believes that the standards adopted by the FCC are sufficient to protect the general public from exposure to RF radiation from wireless communication facilities.

Recommendations

- Assuming compliance with FCC adopted exposure guidelines, the DOH believes that no DOH action is warranted in regard to RF exposures and wireless communication facilities.

- The DOH believes that it is desirable and appropriate to restrict and implement appropriate work procedures in areas such as rooftops where the potential exists for RF exposures to exceed FCC standards.

- The DOH believes that research on the effects of exposure to RF radiation from wireless communication facilities should remain on the national and industry agenda.

The DOH should continue to monitor the results of research into the possible health effects and RF exposures, and revise these recommendations as needed.

Additional Information

To obtain a copy of the FCC Tower Siting Fact Sheet go to the FCC's Internet web site: http://www.fcc.gov/wtb/tower.html or via fax on demand at (202)-418-2830, document number 6507

NCRP 86. "Biological Effects and Exposure Criteria for Radiofrequency Electromagnetic Fields"

NCRP 119. "A Practical Guide to the Determination of Human Exposure to Radiofrequency Fields"

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